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TO THE

STUDY AND FORECAST OF WEATHER.

BY

W. CLEMENT LEY, M.A.

Published by Authority of the Meteorological Council.

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PREFACE.

THE chief object of this Manual (which has been prepared at the request of the Meteorological Council by the Reverend W. Clement Ley, Inspector for England of the Meteorological Office,) is to facilitate the study of Weather to persons who are in a position to avail themselves of the usual meteorological instruments (the Barometer and the Thermometers, dry and wet bulb), and who wish to bring their own local observations into connexion with the more general information supplied by the Daily Weather Reports of the Meteorological Office, and with the accounts of weather published in the daily press.

In the treatment of a subject of such complexity as changes of weather, it would be undesirable, even if it were possible, wholly to exclude theoretical considerations, some of which may be open to controversy. The Council have therefore left the Author free to put forward the views as to the immediate causes of changes of Weather to which he has himself been led by long observation and careful study, but they express no opinion of their own as to questions which cannot be definitively answered in the present state of our knowledge.

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AIDS TO THE STUDY AND FORECAST OF WEATHER.

For the use of Observers in the British Isles.

In the following pages a short sketch will be given, firstly, of the most important non-instrumental observations, to which attention should be given by the student of weather who is already familiar with the nature of the most indispensable meteorological instruments, the barometer and thermometer; secondly, of the relations existing between the winds and the distribution of barometrical pressure, these relations being traced both in the general atmospheric currents of the globe, and in our local systems of atmospheric disturbance; thirdly, of the conditions of weather which attend and characterise the last-mentioned systems.

I.

OBSERVATIONS.

Wind.

Taken in connexion with the information given us by the barometer, the changes in the direction and force of the wind are of the utmost importance to the observer who wishes either to understand or to predict the weather.

"Veering" and "backing," of wind.

The wind is said to veer when it shifts with the sun (*i.e.* from left by the front to right, or with watch hands, in the Temperate Zone of the Northern Hemisphere). Thus an East wind in veering shifts to West through South-east, South, and South-west; and a West wind shifts to East through North-west, North, and North-east.

If the wind shifts in the opposite way the change is called "backing." Thus the wind is said to "back" from West to South-west, South, and South-east; or from East to North-east, North, and North-west.

Estimation of force of wind.

The force of the wind is in this country usually estimated according to the Beaufort scale, which is that most generally adopted at sea. The average velocities of the wind in miles per hour corresponding to the several figures in this scale which have been adopted by the Meteorological Office are as follows :—

Force.		Velocity. Miles per Hour.
0.	Calm	3
1.	Light air	8
2.	Light breeze	13
3.	Gentle breeze	18
4.	Moderate breeze	23
5.	Fresh breeze	28
6.	Strong breeze	34
7.	Moderate gale	40
8.	Fresh gale	48
9.	Strong gale	56
10.	Whole gale	65
11.	Storm	75
12.	Hurricane	90

Allowance to be made for local differences.

Wind observations are affected to a serious extent by inequalities of the ground, and by obstacles existing on it, such as trees or buildings, which interfere with the motion of the air, either materially retarding it or causing it to blow in eddies round projecting corners. At sea, close to the coast, the wind is affected to a very large extent by the proximity of the land, especially if there be high land in the neighbourhood. Sailors when rounding projecting headlands, such as Cape Finisterre or Cape Wrath, often find the winds very different in direction on the two sides of the promontory. These differences show the importance of caution in judging of the general direction and force of the wind from any chance observations.

By noticing the motion of smoke from chimneys, and of very low clouds, observers on land will be aided in forming a judgment of the force and direction of local winds. On the coast some information may be gained as to the direction of the wind by observing the direction in which the sea "tops."

CLOUD.

What a cloud is.

A cloud is an aggregate of condensed vapour, *i.e.*, of minute particles, either liquid or frozen, "water-dust," or "ice-dust," floating in the air.

Observation of clouds.

The art of distinguishing the varieties and movements of clouds cannot be altogether obtained from books, and it is only by long study, common as the objects of such a study are, that perfection in this art can be acquired. The remarks which are about to be made on the principal modifications of the clouds are needful, because, when we come to speak of the interpretation of weather signs, we shall have to refer to these modifications; but our remarks will be of little use except to the observer who has already practised weather-watching with assiduity.

The clouds furnish the observer with some of the most valuable indications he can have of the existing atmospheric conditions, for not only does their motion show what winds are blowing above his head, while he perhaps is sheltered by hills, trees, or buildings, but the changes in their form and size also indicate operations in progress in the upper strata of the atmosphere, which he could have no other possible means of detecting than by watching them.

Varieties of clouds.

Cloud varieties may be roughly divided in respect of *apparent form* into two classes: the *fibrous* or *linear*, which tend to arrange themselves in straight lines or streaks; and the *massive* or *compact*, which shape themselves in heaps or piles.* The latter vary in size from fragments of condensed vapour a few yards in thickness to masses whose shortest diameter is several miles. As, however, clouds of all altitudes present both these varieties, and as their relative level is as important as their shape, we shall describe the cloud-formations in an order generally descending, and commence with the highest form in which condensed water-vapour is visible.

Cirrus.

The altitude of Cirrus is very great, as this form of cloud is seen far above the highest mountain peaks that have been ascended, and over the heads of the most adventurous voyagers in the balloon. Cirri sometimes lie in very fine delicate strands like gossamer threads; at other times they are collected in downy wisps like bunches or tufts of white hair, which has led to their being called "mare's tails;" at other times they are arranged in a spray of small white feathers, the separate fibres looking as if kept asunder by electrical repulsion, and commonly pointing upwards, but frequently, also, especially in dry weather, having a downward direction.

When increasing, these clouds form an interlacing network or sheet of filmy ice-mist, which is often seen over one side of the sky, while the other remains temporarily clear. We shall learn further on that the positions of these sheets, as well as the direction from which the cloud is seen to move, supply us in many cases with useful prognostics of coming weather.

Cirro-stratus.

As the veil of cirrus becomes denser it forms what is termed Cirro-stratus. It is this cloud which produces "halos" round the sun or moon. The most usual form of halo is a simple white ring, ordinarily of about 22½° radius. However, the solar, and sometimes the lunar, halo exhibits the prismatic colours. With the appearance of halos is occasionally combined that of "mock suns," or "mock moons," sometimes with fantastic but symmetrical arrangements of supernumerary circles. The existence of halos is physically explained on the hypothesis that the higher clouds are composed of ice-crystals, and they are more strikingly developed the higher the latitude of the observer.

---

* These classes cannot always be separated when the clouds are near the zenith, and only their under surfaces are seen: viewed laterally they are easily distinguished. It is important, however, to notice that the thread-like appearance of those clouds whose vertical diameter as compared with the horizontal is small is always partially, and often wholly, due to perspective. Whether partially or wholly so we can at once decide by looking at the same kind of cloud in different azimuth; *e.g.*, the bands of "Cirrus" are *real*, since they appear to converge in opposite points of the horizon; streaks of "Stratus" are mostly *phenomenal* only, since looked at all round the vault of the sky at the same distance from the zenith, they are commonly seen as lying in the same apparent plane.

The halo must be distinguished from the "Corona," which is a series of coloured rings surrounding the moon, produced by the passage of thin clouds, usually at a moderate elevation.

Nimbus. As the sheet of Cirro-stratus increases in density the threads become indistinguishable. The condensation of vapour is now slowly propagated downwards. Lower forms of cloud then usually combine into a thick watery-looking canopy, and an aggregate of composite rain-cloud, or Nimbus, is finally developed.

Cirro-cumulus. Light Cirrus, however, often does not manifest any tendency to pass into Cirro-stratus. Instead of doing so it frequently assumes a more fragmentary or spherical form, and receives the name of Cirro-cumulus. An assemblage of these clouds is well known as the "mackerel sky," and often resembles a flock of sheep lying down, being formed of rounded masses of cloud more or less regularly arranged. True Cirro-cumulus at the highest level often accompanies dry and warm weather. There are, however, some indefinable varieties between this form and the Stratus of a lower level; and these are occasionally seen beneath, or partly combined with, the sheet of Cirrus, or Cirro-stratus.

Turreted Stratus. There is a form of cloud to which the title Cirro-cumulus is sometimes inappropriately given. It floats at a high level, and is a perfect hybrid between the fibrous and the more spherical cloud-forms. Viewed laterally, *i.e.*, when not near the zenith, it appears as a long cord or wreath of level cloud, having numerous very elevated turrets or protuberances of the Cumulus form projecting from the upper surface. It is common only in warm weather, and is most characteristically developed, as we shall see, under particular atmospheric conditions (p. 32).

Stratus. The term Stratus was originally applied to ground fog, but it is convenient to restrict it to the clouds which when continuous form a sheet or canopy, and when detached appear as streaks or bars, in the middle or rather the lower levels of the cloud region. This cloud varies much in altitude. It is more prevalent by night than by day, and the more massive cloud-forms commonly degenerate into the stratiform descriptions soon after sunset.

A peculiar modification of Stratus is common under certain conditions, and must therefore be mentioned in connexion with prognostics. It arranges itself in parallel but ill-defined bars transverse to the meridian, which often coalesce so as to overspread the sky. It only occurs with a somewhat tranquil atmosphere, and rarely with a very high or extremely low temperature, and it may be further distinguished by its uniformly sober tints, in which a bluish grey predominates. It may conveniently be distinguished as "dry-weather stratus."

Cumulus. The lowest clouds are usually more or less of the Cumulus or "woolpack" form. The level, however, of the under surfaces of Cumuli differs greatly on different occasions, and still more so does the altitude to which the upper or rounded portion extends. These clouds may be regarded as a sign of great cold in the region above them. The varieties of Cumulus are many, and ill-defined, but it will be desirable to describe the more distinct forms. Fine-weather Cumulus has a moderate elevation, and a well-defined rounded surface. Its formation and dissipation is governed greatly by the temperature of the day, the cloud frequently beginning to show itself soon after sunrise, increasing till the hottest part of the day, then gradually diminishing, and eventually disappearing about sunset. This form of Cumulus is comparatively uncommon over the surface of the sea in our latitudes, and it may often be seen from a great distance marking the position of a coast-line, or even of small islands. Showery-weather Cumulus is remarkable for the rapidity of its formation and disappearance, and for the readiness it displays to pass into other cloud-forms. Large and well-developed Cumuli are usually called "thunderclouds," from their prevalence in periods of electrical disturbance; but it is worthy of observation that electrical discharges never appear to take place in any form of cloud until its summit (though this of course is not always visible) has begun to spread outwards or upwards in a more or less cirriform shape, and has exchanged its hard for a softer outline. When Cumulus has thus attained a great size it becomes a shower-cloud. In this case it is commonly denominated Nimbus, the title having, unfortunately, been given by Howard indiscriminately to the extensive composite cloud-banks already mentioned, whose formation is in a downward direction, and to the passing showers produced by the upward development of local Cumulus, and, in short, to all the forms of rain-cloud. In the present work only the great banks of composite rain-cloud will be designated as Nimbus, and the local shower-cloud will be simply termed "Shower-cloud."

Shower clouds.

"Pocky-cloud;" how formed.

Although the under surface of Cumulus is commonly flat, it is sometimes rugged and mammillated. In this form it is known by the sailors of the Orkneys as the "Pocky-cloud." If the rounded forms of the ordinary woolpack are due to the introduction of a mass of warm air and the consequent condensation of vapour in a cold atmosphere, we probably have in the "Pocky-cloud" a moist upper layer brought into contact with a colder stratum below. Other descriptions of cloud have similar modifications, thus Cirro-stratus not unfrequently exhibits pendulous hanks or wreaths on its under surface, when the temperature of the lower region of atmosphere is falling, and a colder wind is setting in beneath.

"Scud.

Detached fragments of Cumulus, particularly when near the earth, are often as irregular in contour on their lower as on their upper surfaces. The term "Scud" is commonly applied to all low loosely-formed clouds, when drifting rapidly before the wind. Other varieties are scarcely sufficiently significant of special atmospheric conditions to merit description here; our present object being not so much to classify the cloud-forms, as to direct the attention of the observer to certain modifications, the study of which is important in forming a judgment of weather.

WEATHER SIGNS.

Appearance of landscape and sky.
Value of local signs.

The observer who wishes rightly to interpret the conditions of the weather, and to foresee its probable changes on definite and well-understood principles must not on this account neglect those signs on which the less scientific weather-watchers chiefly rely. Fishermen, shepherds, game-keepers, and other men whose occupations oblige them to be out of doors at all hours and in all weathers, can often make *for their own district* from local signs, a good guess as to the chances of weather for a day or two in advance, and the meteorologist, with apparently the most complete machinery for obtaining weather knowledge at his command, should gladly gain information as to these signs from many an old countryman who can barely read and write, but whose wits for weather wisdom have been sharpened by his mode of life.

Of the signs, however, to which we refer, many are extremely local, and the specially weather-wise men who rightly interpret them in their own district would be quite at a loss if taken out of it and asked to form a judgment of coming weather in a different part of the country from the local signs known there. Particular mention of these signs would, therefore, in a work intended for general utility, tend to embarrass and mislead; and perhaps the only safe rule which can be laid down is simply, "Mistrust all rules. Study all supposed weather "signs, and collect all available information thereon, and from "those signs which appear in your part of the country to be "well authenticated, deduce such inferences as our present know-"ledge of atmospheric phenomena shows to be probable."

Three examples of the sort of inferences alluded to will suffice:

Clearness of atmosphere.

1. Unusual clearness of the atmosphere is commonly taken as a token of impending rain or storm. As the old ballad of Sir Patrick Spens has it—

> I saw the new moon late yestreen,
> Wi' the auld moon in hir arme;
> And if we gang to sea, master,
> I fear we come to harme.

(It is only when the atmosphere is remarkably clear that we see the appearance of the dark side of the moon, described as "the new moon in the arms of the old one.") Now the removal of the dust particles with which the atmosphere, in settled, and therefore somewhat calm and dry, weather, is much charged, is an early indication that either condensation of vapour, or rapid movement of air, or both, has begun to occur in regions immediately to windward of the observer; and consequently that the latter is now within, or nearly within, a system of atmospheric disturbance. Such a system, as will hereafter be shown, is rarely either stationary or solitary. The advent of rain and wind is therefore indicated as probable by unusual clearness of the atmosphere. But it is impossible to form a safe judgment as to the degree of this probability in any individual case without a knowledge of the system of atmospheric currents prevalent at the time.

This same inference is extended a little further in the instances in which "visibility," as this uncommon transparency of the atmosphere is called, is accompanied by great refraction, very distant objects being apparently brought up above the horizon and rendered visible, for in such instances we know that the rays of light which reach our eyes have passed through closely contiguous strata of air of unusually varying densities and temperatures, the probable commingling of which increases the likelihood of condensation, if other circumstances are favourable thereto.

Colours of ting and rising sun.

2. It is commonly said that "a rosy sky at sunset presages " fine weather, a red sky at sunrise bad, and a grey sky fine " weather." So long as this generalization is treated simply *as a rule*, irrespective of the principles of weather prognosis which will be explained in the following pages, it will often be found extremely fallacious; but if we take pains to draw an inference as to the distribution of aqueous vapour in the atmosphere from the colour of the sky, we shall find that the latter frequently furnishes us with information which may be employed, as subsidiary to our principles, with much practical utility.

The redness of the sun when near the horizon is due to diffraction. Particles suspended in the air, whether dust, smoke, or *very minute* globules of water, give a red colour to transmitted light, the particles obstructing and reflecting the rays of small wave length more than those of great wave length. This is the reason why in large towns the sun, both rising and setting, nearly always appears red. In the country, the red colour which the rays acquire in passing through a long stratum of air is probably in large measure due to water globules forming an extremely fine mist. At sunset, after the evaporation which has taken place during the day, these globules are usually present in large quantity at the time when the air is rapidly becoming cooler, and the sun therefore usually appears somewhat red. During the further cooling which occurs in the night, many of the particles are commonly deposited in dew, fewer remain suspended in the air, and the rising sun is therefore less usually red. A red sunrise indicates that, after this precipitation, the atmosphere still contains a large quantity of water-particles, which, after the evaporation about to occur in the next few hours, is likely to form rain clouds. A grey sky in the evening is commonly caused by the presence of an amount of cloud in the west which is sufficient to stop the direct rays of the sun, and to allow nothing but diffused light to pass.

Position of rainbow.

3. Almost everyone has heard the common weather proverb in the doggrel,—

A rainbow in the morning
  Is the shepherd's warning;
A rainbow at night
  Is the shepherd's delight.

The bow must, of course, always appear in the opposite point of the sky to the sun's position. In the morning, then, the bow is in the west, and the rain is consequently falling on that side of the observer. In the evening, on the contrary, it must appear in the east, the rain must accordingly be falling to the eastward of our station, and the clouds on the opposite side must have cleared, at least to a sufficient extent to permit the sun's rays to pass through them. Taken in connexion with the principle, which will be presently explained, that rainfall tends in a general way, in our latitudes, to propagate itself from west to east, and also with the fact that our winds, especially in showery weather, are most commonly from westerly points, and viewed in relation to the particular atmospheric conditions prevailing at the time, the appearance of the rainbow at the different periods of the day becomes to a certain extent significant.

II.

RELATIONS OF PRESSURE AND WIND.

General Laws.

Correlation of atmospheric pressure, wind, and weather.

Changes of weather are closely related to changes of wind, and changes of wind to changes in the distribution of atmospheric pressure. It would not indeed be safe to assert that the weather conditions are, in all cases and absolutely, the effects of atmospheric currents, or that the atmospheric currents are absolutely the effects of the distribution of pressure; for, as we shall see, the interaction between these several elements is not quite so simple as would be conveyed by such an assertion. It will nevertheless be desirable, for the sake of clearness, to speak first of the distribution of pressure in its relation to wind, much as we should do if it were simply the cause, and in no sort of sense the effect, of wind; and later on to treat of wind in its relation to weather, just as if our winds entirely determined our weather.

Winds, how produced.

When the atmosphere is in a state of equilibrium no movement of air can of course occur, but as soon as the equilibrium is disturbed a current of wind is generated, the air tending to move from the district of greater to the district of less pressure; in other words, the heavier air tending to drive out the lighter. Absolute equilibrium is in nature hardly ever attained, the air being kept in almost perpetual agitation by changes of pressure. The prime cause of atmospheric disturbance is found in the unequal distribution of solar heat over the earth's surface; in the changes, diurnal and seasonal, in that distribution; and in the unequal effects thus produced on the tension of the air itself and of the vapour suspended in it.

Effect of earth's rotation on winds.

But as soon as a current is established the direction of its movement is affected by other forces besides that of gravity. The effect of the earth's rotation on its axis is to cause every current to deviate to the right of what would otherwise be its course in the Northern Hemisphere, and to the left in the Southern. The winds thus blow to a certain extent *round* instead of *directly into* any area in which the pressure of the atmosphere is relatively low, and the centrifugal force of the currents themselves helps in this case to maintain the inequality of pressure. This effect of the force of the earth's rotation varies with the latitude. In the high latitudes we find that if we describe lines along which at any given time the pressure of the atmosphere at the level of the sea is equal, while it is higher on the one side and lower on the other, the wind blows in a direction which, for practical purposes, may be regarded as parallel to those lines. In low latitudes, on the other hand, the winds move more nearly at right angles to such lines, and at the Equator the deflecting effect of the earth's rotation is zero, and the air must consequently there travel in direct lines from the points at which the pressure is greatest to those at which it is least. The amount of deviation* (to the right in the Northern Hemisphere and to the left in the Southern) appears to be further affected by the amount of friction which the currents encounter in traversing the surface of the earth, being diminished when the friction is increased.†

he barometer s a "weather lass."

The barometer is popularly called a "weather glass," and it is obvious from what has been said, that the information given by this instrument is intimately connected with the conditions of the weather. But it should also be obvious that this connexion is not of a simple character, and that the several relations which constitute it must be patiently studied if we are to understand the connexion correctly or to employ our knowledge usefully. People may often be heard to remark that "the barometer," though in good working order, "proved wrong" on such an occasion, or "was right" on another. Such expressions could not be employed by anyone who had the faintest idea of the intricacy of the connexion between the readings of the instrument and the prognostics of weather which may be derived from it. We cannot, from the conditions of pressure prevailing at any given time and place, leap with safety at once to any conclusions as to probabilities of the weather, local or otherwise, that is coming, but must be content to plod quietly through the different steps which in this case lead from the premises to the conclusion. The words "change," "fair," "rain," &c., which are placed on the scales of many barometers, have tended to increase the misapprehension of the use of the instrument, as indicating a simplicity of relation which does not in reality exist.

sobars.

A line, such as those already alluded to, drawn through those stations at which at any given time the readings of the barometer are the same, is called an "isobar" or line of equal pressure; and the winds prevailing at the time in the vicinity of those stations will, in our own region of the globe, be nearly parallel to this line, and have an area of lower atmospheric pressure on their left and one of higher on their right.

Buys Ballot's aw."

This relation between wind and pressure is traceable in several older writings, but the credit of having persistently urged it, until it has met with general acceptance, is due to Professor Buys Ballot of Utrecht, after whom it is generally called "Buys Ballot's Law." According to this law we can tell what wind is blowing at any time at any station, if we know the readings of the barometer

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[*] By "deviation" is meant the degree in which the movement of the air differs from what it would be if unaffected by the earth's rotation. Thus the expression "angle of deviation" is sometimes employed to designate the angle which the direction of the wind makes with a line drawn perpendicular to the isobar on the side on which the pressure is the lower.

[†] For some account of this effect of friction on the direction of the wind see Journ. Scottish Met. Soc. Vol. IV., No. XXXIX., Ferrel, "Relation of Wind to Barometric Gradient." Guldberg and Mohn, "Études sur es movements de l'Atmosphère."

taken at the time at a number of stations situated on various sides of it, within a distance of 100 or 200 miles.

The Law is—

> Stand with your back to the wind and the barometer will be lower on your left hand than on your right.

Thus the wind may be expected to be—

Easterly, when the pressure, or the barometer reading, is higher in the North than in the South;
Southerly, when pressure, or barometer reading, is higher in the East than in the West;
Westerly, when pressure, or barometer reading, is higher in the South than in the North;
Northerly, when pressure, or barometer reading, is higher in the West than in the East.

Relation of wind force to distribution of pressure.

The reader who has thus far understood the relation between the distribution of barometric pressures and the direction of the wind will be prepared to extend it further to the velocity with which the wind moves. Water will flow more rapidly the steeper the slope of its channel; and air, under similar conditions, is similarly influenced. It is therefore clear that the motion in a body of air between two stations, or the wind, will in a general way be governed in respect of velocity by the difference of barometrical readings across the given geographical space.

"Atmospheric gradients."

The steepness of a slope is measured by the proportion between its vertical height and its horizontal length, and engineers speak of a slope or gradient of 1 in 60, 1 in 100, &c. The use of the term "gradient" as applied to differences of atmospheric pressure, first suggested by Mr. T. Stevenson, C.E., of Edinburgh, has been generally adopted in this and other countries.

These atmospheric gradients are not referred to the same units of scale in the vertical and horizontal directions. The vertical scale is in units of barometrical readings, and the horizontal scale in units of geographical measurement. The unit of distance for the measurement of barometrical gradients now generally adopted is 15 nautical miles.* Thus, when it is said that between London and Scarborough there is on a given day a gradient of ·025 for westerly winds, it is meant that the isobars lie West and East, and that the barometer in London reads higher than that of Scarborough, by a difference amounting to ·025 for each unit of 15 nautical miles between the two stations. Similarly when we speak of a gradient of ·015 for easterly winds between Holyhead and Brest on another occasion, we mean that isobars on that occasion lying West and East, the barometrical reading at Holyhead was higher than that at Brest, and that the difference amounted to ·015 per 15 nautical miles.

Gradients, as thus measured, are rarely higher than ·04, or ·05 in our islands, though much higher values than these are occasionally recorded in very severe storms.

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* This unit was adopted as most convenient by the Permanent Committee of the Vienna Congress, as securing uniformity between the gradients of the British scale and those expressed in millimetres per 60 nautical miles.

In a general way it may be said that gradients are slight or moderate when below ·01, and steep when above ·02.

The greater, then, the difference of barometrical readings, as measured in the direction in which the difference is greatest, (or the nearer together the isobars on a weather map) the stronger may be expected to be the force of the wind over the district in which the readings occur. Mention has already been made of the fact that the wind is obstructed by inequalities of the earth's surface, and it is evident that the varieties in the conformation of the ground and the obstructions with which it is covered, render it impossible to construct any definite scale of relation between gradient and wind velocity, except for the surface of the open sea, even if the relation were not affected by other than local causes. But it appears certain that the mobility of the atmosphere is affected by other influences, the nature of which has not yet been fully investigated, and it is probable that conditions of temperature, humidity, and actual pressure (as well as the friction of cross-currents overhead) may modify to a considerable extent the actual wind occurring at any particular time, irrespective of locality. Thus much is known, that in the British Islands the relation between the gradient and the force of the wind is subject to marked variations,* and that in lower latitudes, where, as we have seen, the wind blows more from the regions of high to those of low pressure than it does with us, the difference of barometrical readings corresponding to a given velocity of wind is less than in our latitudes.

Caution equisite in stimation of gradient.

A certain amount of questionable hypothesis enters into the measurement of atmospheric gradients, whenever we have to employ, in estimating them, barometrical reports from stations of very different height reduced to their supposed equivalent values at sea level; because there is reason to believe that the relations of pressure, and consequently the direction and amount of gradient, are on many occasions different in different strata of the atmosphere. It is not necessary to enter further into this subject in these pages. For our immediate purpose it will be sufficient for the reader to have understood what is meant by "steep" or "high," and by "slight" or "low" atmospheric gradients, and to have formed a general conception of the connexion which exists between the wind and the distribution of barometrical pressures.

DISTRIBUTION OF MEAN PRESSURES AND PREVALENT WINDS OVER THE GLOBE.

Application of laws above escribed.

The next step is to show the application of the laws above explained to the actual movements of the atmosphere prevailing on the earth's surface. It would be possible to do this with reference only to the climate of our own part of the earth, but such a mode of handling the subject would not be satisfactory, for the more local conditions of wind and pressure are intimately connected with the great currents which traverse the surface of the globe. A brief and general description of these will now be given, to be followed by a more minute analysis of the forms of atmospheric circulation prevalent in the west of Europe in particular.

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* Quart. Journ. of the Met. Soc., October 1876.

Plate I.* shows the mean distribution of pressures (reduced to sea level and gravity of lat. 45°) and winds of the globe for the month of January, and Plate II. that for July, so far as these have hitherto been determined.

Two general facts are taught by an examination of these plates. The first is traceable to a certain extent in either of the plates. The second comes out only on a comparison of the two.

Great areas o high and low barometer.

The first of these facts is that, roughly speaking, the atmosphere which envelops our earth may be divided in respect of barometric pressure into five great areas. A belt of moderately low pressure shows itself over the equatorial region. North and south of this are two belts of high pressure. Proceeding into higher latitudes, we find areas of low pressure around the poles.

Interfering to a large extent with this first statement, we notice in the second place that in the winter season of each hemisphere the continental districts are occupied by areas of high barometrical pressure, and that these are replaced in summer by areas of low pressure. This annual change depends (still speaking roughly) for its amount on the size of the continent; and the inference is obvious that it is due, in great measure, to the effects of solar heat upon the atmosphere over land and water respectively. The atmosphere over the interior of a continent during the winter season is more chilled and condensed, and is consequently heavier than over the sea; in summer, on the other hand, it is more rarefied, and is therefore lighter over the land than over the sea.

Prevailing winds of glob

The prevailing winds, shown by the arrows in the plates, are determined by the interaction of these two general laws, and it will be seen that these winds, as regards the relation between their direction, and the distribution of pressures, follow the law explained on pages 9–11. Thus over the Atlantic and Pacific Oceans the air currents pour out of the Northern and Southern belts of high pressure into the equatorial belt of low pressure, the latter shifting its position northward or southward according to the season of the year. On the polar sides of the belts of high pressure westerly winds prevail, blowing round and into the polar areas of relatively low pressure. Around the continents the winds exhibit seasonal variations, in great measure determined by the extent and configuration of the areas of high and low pressure which are produced over the land in winter and summer respectively.

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* It should be clearly understood that the mean isobars given in these plates (constructed in the summer of 1879) are, as regards many important districts of the globe, to a large extent hypothetical. We possess, *e.g.*, very few data indeed from which the mean pressures over the greater part of the Pacific Ocean can be determined with anything like accuracy at present. In charts of this description numerous corrections have been and will be introduced by the progress of meteorological inquiry.

It may be advantageous, however, to bear in mind that in order approximately to determine the mean barometric pressure for any locality we are not always under the necessity of possessing actual barometric returns from that locality. By the employment of the principles indicated in these pages we can commonly determine without risk of very large error, especially over the oceanic districts, the mean pressures for any locality, provided we are in possession of an adequate number of wind and barometer reports at any station or stations at no great distance therefrom.

Prevailing winds in January.

The chart for January (Plate I.) shows us that at that period of the year the prevailing winds over Canada are North-westerly, the belt of this air current extending in fact nearly from the Mississippi to Davis' Straits. Further to the Eastward, over the western portion of the North Atlantic, the prevailing air current is from the West, while from the Azores up to the extreme northern point of Siberia an extensive South-westerly wind prevails. Two prolongations or arms are observed to extend from the area of low pressure whose centre lies to the south of Iceland, one of these stretching North-westward to Baffin's Bay, the other North-eastward over the Arctic Sea. An area of relatively high pressure existing over Greenland, Northerly and North-easterly winds are experienced in the high latitudes of the Atlantic and the Polar Seas. The area of reduced pressure over the northern portion of the North Pacific is somewhat similar to that over the North Atlantic, but does not extend into such high latitudes. North-westerly winds therefore prevail at this season over the eastern portion of the continent of Asia, sweeping round through Westerly and South-westerly to South-easterly winds between Behring's Straits and Vancouver Island. Over the greater part of North America a well-marked area of high pressure exists at this season, the nucleus of which is nearer to the Pacific than to the Atlantic coasts, a fact which is probably due to the retention or banking up of the cold and dense atmosphere by the Rocky Mountains, which render it less easy for the air to escape westward towards the Pacific than in an eastward direction, where the earth's surface presents fewer obstacles to its movements. A corresponding, but very much greater and more remarkable area of high pressure, covers nearly the whole of Asia. This area has a somewhat similarly shaped nucleus, which, probably for a corresponding reason, lies near the eastern shores of the continent.

South of latitude 30° N. we find predominant North-easterly winds round the greater portion of the globe, extending in most regions to the Equator. In the Indian Ocean these air currents cross the Line, and, changing their direction in obedience to the law of relation between wind and pressure for the southern hemisphere, there blow from North-west and constitute a North-west "Monsoon," or periodical wind.

January being a summer month in the Southern hemisphere, areas of low pressure are exhibited over the interiors of the Southern Continents, South America, the Southern part of Africa, and Australia, around which the winds necessarily tend to circulate in a direction from the front towards the right hand. These last-mentioned continental districts form at this season interruptions in the Southern hemisphere high-pressure belt.

To the South, again, of this belt the mean pressure rapidly decreases, and, as far as ships go, south of latitude 40° S., Westerly and North-westerly winds appear to be predominant round the globe, blowing with a force and persistency which has given to this region, in the language of the sailors, the title of the "roaring forties."

Change in spring.

In the spring of the Northern hemisphere a great and rapid change takes place in the distribution of mean pressures over that half of the globe. This change is least marked in the oceanic districts of the high-pressure belt. Over the interior of the continents the barometers fall briskly, this change being much the most serious over the southern part of Asia. At the same time, and owing probably to this dislodgment of a portion of the atmosphere from the continental districts, a marked though temporary increase of pressure occurs in high latitudes, a fact to which the North-easterly surface winds, so frequently experienced in the British Isles at this season, seem to be due. The equatorial zone of low pressure is now travelling northwards, and over a portion of the North Indian Ocean, where this zone coalesces with the continental area of low pressure, the winds which are felt as the South-east Trade on the South of the Line, are felt on the North of it as an incipient South-west Monsoon.

This being the autumn of the Southern hemisphere, pressure is increasing over the southern portion of South America, South Africa, and Australia.

Prevailing winds in July.

Most of these changes have reached their consummation in July (see Plate II.) Mean pressure is now low over the interior of North America, the major axis of this depression nearly coinciding with that of the figure of the continent. A similarly shaped, but far vaster, depression lies over Central Asia, causing the winds in the extreme east of Europe to become North-westerly. The area of very low pressure noticed over the North Atlantic in our winter has now almost ceased to be traceable. The equatorial zone of low pressure has crossed the Line on the Atlantic side and apparently on a portion of the Pacific side also; and the South-east Trades, where they penetrate into the Northern hemisphere, are felt as South-westerly winds in lower northern latitudes. The conditions already described as showing themselves over the North Indian Ocean in spring are now greatly intensified. Meanwhile the depression noticed in winter in South Africa (p. 14) has crossed to the northern portion of that continent, causing predominant Northerly winds over the Mediterranean. In the Southern hemisphere, the high-pressure belt is now very wide and well marked, and appears to extend round the globe.

Change in autumn

In our autumn the general changes are the reverse of those noticed during the spring, and their character may therefore be easily inferred. It will be sufficient here to call attention to the rapid development of the area of low mean pressure in the neighbourhood of Iceland about the time of our usual autumnal storms, as contrasted with the increase of the Northern pressures in spring.

Upper currents.

One inference deserves mention here. Since the winds, in respect of one component of their motion, flow across, and not directly along the lines of equal pressure, it is obvious that in order that the pressure areas should be maintained the circulation of the atmosphere must be vertical as well as horizontal; that is to say, whatever air passes over the earth's surface from the areas of high pressure to those of low must be restored in upper-currents from the latter to the former. Observations on the movements of the higher clouds bear out the truth of this statement. The return currents over the Trade-winds are frequently noticed; and in our own latitudes it is observed that when you stand with your back to the wind the movement of the higher clouds is most commonly a little from your left hand to your right.

IRREGULAR FLUCTUATIONS OF PRESSURE.

The reader must be warned against a possible misconception of the meaning of the preceding paragraphs. The plates give only the lines of *mean* pressure, and the directions of *prevailing* winds for the two months to which they refer, not the actual pressures or actual winds existing at any given date, or indeed for any given January or July.* The latter are far less simple than the plates looked at by themselves might lead us to suppose. It is true that in lower latitudes the irregular fluctuations of the barometer are, except on rare occasions, extremely small, but in higher latitudes they are very great. Shifting areas of relatively high and low pressures are perpetually traversing the surface of the globe in the Temperate Zones, accompanied by those variable systems of atmospheric circulation which give to our winds their proverbial changeableness. In these latitudes the great areas of high and low pressure shown in the plates represent in point of fact, the prevalence in each district of the temporary and shifting systems of barometric elevation and depression respectively. Thus it happens that, *e.g.*, in the district of lowest mean pressure over the North of the Atlantic, shown in Plate I., the actual barometric readings vary from about 1·5 inch above to about 1·6 below the mean for the season.

Are their laws known?

Do the laws by which these fluctuations are governed fall under our cognisance? Are we acquainted with the special forms and contours of the variable areas of high and low pressure? Is their movement over the surface of the globe determined by conditions which we know? And, again, are they characterised by particular and definite states of weather in relation to temperature, state of sky, appearances of cloud, amount of rainfall, and the like?

It is obvious that on the answer to be given to these questions depends the whole status of our weather knowledge. If that answer were a simple negative, this knowledge would scarcely be above the level of an instinct, similar to that of the bees which fly to the hive whenever a dark cloud covers the sun; in the place of rules we could have nothing but conflicting experiences; and to attempt to write a Weather Manual would be to undertake an impossible task. If on the contrary the laws of the atmospheric changes lay completely within the circle of our knowledge, weather wisdom might at once claim its place among the exact sciences; and it would be possible to establish fixed and definite rules, by the aid of which the observer could foretell coming weather with absolute certainty. If, however, as is the case, the truth lies between these extremes, if some of the conditions can be traced, while others are unknown, then weather wisdom is neither a mere instinct nor an exact science, but a scientific art, containing both possibilities of instruction and elements of progress, and it becomes advisable to tread as carefully as possible through the border between knowledge and ignorance, pointing out with as much accuracy as possible the limits of the two provinces.

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* In illustration of the extreme variation which occasionally occurs, it may be mentioned that over North-western Europe and the adjacent portion of the Atlantic the mean pressures and prevailing winds for June, 1879, were in almost precise accordance with the mean pressures and prevailing winds ordinarily found in the month of December in that part of the globe.

The reader must not expect too much. The sum total of what has been hitherto ascertained on the subject is not very great, and such general rules as we shall be able to give will be easily contained in a few pages. They are, however, essentially dependent on and interwoven with principles which cannot be explained with great brevity. In dealing with the latter the discussion of theories on which meteorologists are not yet agreed will be as far as possible avoided, and only such results of observation will be given as appear useful for the practical object in view.

CYCLONIC AND ANTICYCLONIC SYSTEMS.

The study of any series of daily isobaric charts for our own district of the globe, *e.g.*, the 6 p.m. daily weather maps in the "Times," or the 8 a.m. maps issued by the Meteorological Office, will show that the shapes of the areas which are bounded by the isobars, while subject to immense and almost perpetual variation, are not absolutely and entirely irregular. Particular forms are frequently reproduced. These forms are, as it will be already understood that they must be, attended by special systems of winds, and it will presently be seen that they are further distinguished, both by their concomitant conditions of weather, and by other characteristics. These facts furnish us with a certain rough, but very important, basis of classification. We divide the areas into "CYCLONIC," and "ANTICYCLONIC," and we shall now describe what is meant by these terms. The name "cyclone" was originally applied only to the hurricanes of the lower latitudes, which have long been known to be revolving eddies of air in which the wind circulates around an area of reduced barometric pressure. Since, however, the laws which connect the wind with

The term "cyclone."

the distribution of pressure have been shown to be universal, it is obvious that around any area of reduced pressure the wind must circulate in the same general way as it circulates in a tropical hurricane, the curves of the currents depending on those of the isobars, and the force of the currents on the proximity of the isobars, as already explained. Now the areas of reduced pressure, though subject to great variety of figure, approximate, generally speaking, to circular or oval forms, as we should, from our general knowledge of the motion of fluids, expect to be the case. All such systems of reduced pressure, and their co-existing systems of currents, are therefore spoken of as "cyclonic." The correlative of this term is applied to those areas in which the pressure of the atmosphere is higher than that in the surrounding regions, and around which, therefore, the winds circulate in an opposite direction to those of the cyclones. It may be remarked that the steeper the gradients around the centres of low pressure, the more, as a general rule, do the interior isobars tend to assume a circular form (which also is what we should have anticipated), and also that steep gradients are more common in cyclones than in the anticyclones.

Caution as to meaning of the terms.

Here the reader should be warned against another possible misapprehension. The terms "cyclone" and "anticyclone" do not refer to the *actual* level of the barometer within the areas to which they are applied, but to its level *relatively* to the level in surrounding districts. The observer may find the mercury in his barometer above its mean height, and yet may *possibly* be situated at the centre of a cyclonic system at the time, because the mercury may be still higher at all stations at a certain distance from his own. Contrariwise he may find the mercury in his barometer below the mean, and yet may be at the centre of an anticyclone, because the barometers on all sides of his station may have lower readings at the time than his own. This last occurrence, however, is in our country (in which the anticyclones are altogether less perfectly developed than the cyclones) too unusual to merit further notice here.

Deep cyclone.

The following figures will illustrate what has been said in the two preceding paragraphs. Figs. 1 and 2 represent the isobars and winds* over our area when the centre of a cyclonic circulation existed within it. In the case shown in Fig. 1 the central pressures were both relatively and actually low. Gradients were also generally steep, and the winds were therefore for the most part strong in force. Gales were experienced at the exposed stations in the North-eastern and South-western parts of this depression, where the barometric differences were greatest, while on the North-western side, where they were least, the current was far less rapid.

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* Arrows fly with the wind:
⊙ = Force 0 to 1.
→ = „ 2 „ 4.
⟶ = „ 5 „ 7.
↣ = „ 8 „ 10.
⤖ = „ above 10.

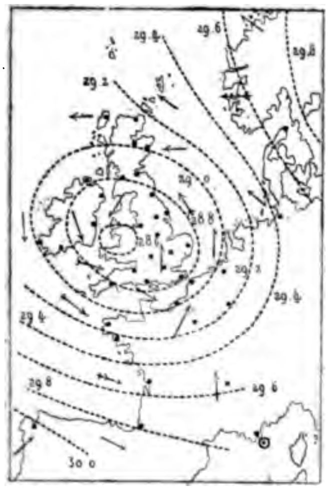

Fig. 1. — 29 Nov. 1874. 8 am.

Cyclone centre over England, readings low.

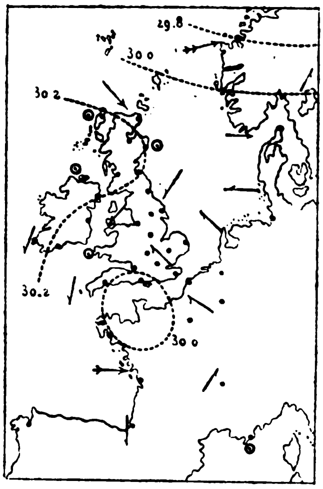

Fig. 2. — 29 Oct. 1874. 8 am.

Cyclone centre over the Channel, readings high.

Shallow cyclone.

In Fig. 2 we have a specimen of a cyclonic system in which the central pressures while relatively low were actually somewhat high. This case affords an illustration also of a very "shallow" disturbance where gradients were nowhere steep, and the winds were consequently very light.

Anticyclone.

Fig. 3 shows us an anticyclone, having central pressures both relatively and actually high. In this instance gradients on all sides were slight, and the winds therefore light or moderate in force.

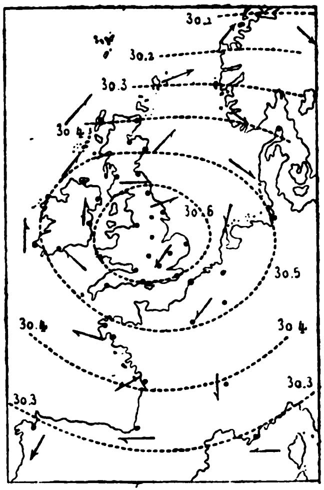

Fig. 3. — 4 Feb. 1874. 8 am.

Anticyclone.

In the central districts of each of the cyclonic and anticyclonic systems the gradient is of course *nil*, and the atmosphere is calm.

Irregular figures.

In the illustrations above given the interior isobars form tolerably symmetrical figures. They are, however, commonly less regular than in these examples. Thus "interfering" cyclones and anticyclones are by no means uncommon Occasionally, too, by the union of several systems, there are produced belts or strips of relatively low or high pressure, to which the terms "cyclonic" or "anticyclonic" can scarcely be appropriately given.

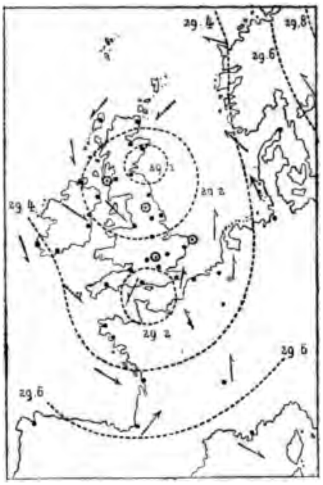

Fig. 4. — 1 Dec. 1877. 8 am

Interfering cyclonic systems, winds variable.

The instances above given have been chosen as affording typical examples of circulations of limited extent, lying pretty completely within the area of the Daily Weather Maps. Circulations of great extent are, however, very common, and at a great distance from the centres of these systems the curvatures of the currents, as shown over a small area, are so slight that the winds within such an area appear to blow almost in straight lines.

Interfering cyclones.

The types mentioned in the last paragraph are fairly illustrated in the figures which follow. Fig. 4 shows us interfering cyclonic circulations on a small scale. The area of the Daily Weather Maps is in this case occupied by highly variable currents, several distinct barometric minima occurring within it at the same time. But even in this instance the relations of the winds to the isobars are traceable with some distinctness.

Interfering anticyclones.

Fig. 5 affords a somewhat analogous example of several con-

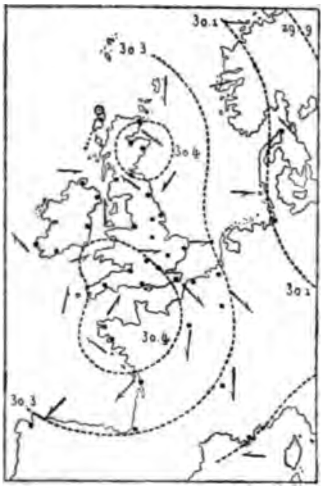

Fig. 5. — 3 Feb. 1874. 8 am.

Interfering anticyclonic systems, winds variable.

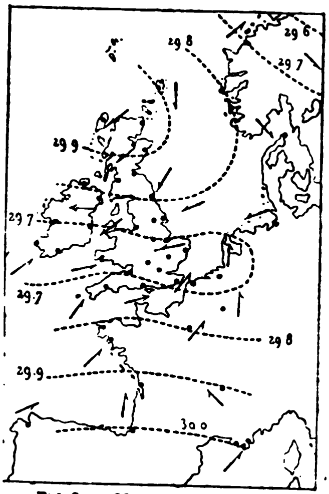

Fig. 6. — 22 Sept. 1875. 8 am.

Belt of low pressure between two areas of high pressure.

tiguous centres of relatively high pressure, also productive of very variable winds.

Belt of low pressure.

Fig. 6 (see page 21) is an instance of a belt of low pressure lying between two areas of comparatively high.

Belt of high pressure.

In Fig. 7 we have a corresponding strip of high between two districts of low pressure.

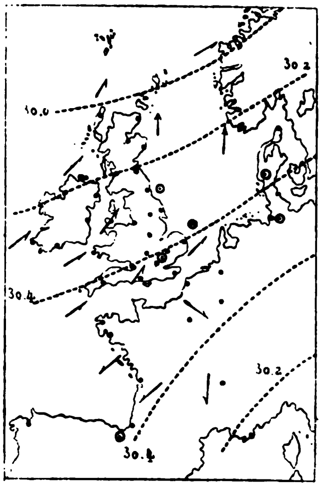

Fig. 7. — 4 April 1876. 8 am.

Belt of high pressure between two areas of low pressure.

Fig. 8 shows us rather straight isobars with very extensive southerly winds.

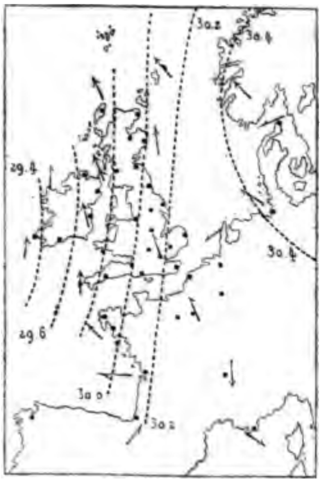

Fig. 8. — 1 Jan. 1875. 8 am.

Typical isobars with southerly winds.

Fig. 9 again represents nearly straight isobars with extensive northerly winds.

Northerly winds.

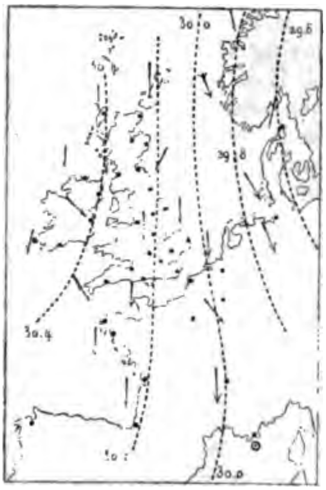

Fig. 9.— 8 Oct 1877 8 a.m.

Typical isobars with northerly winds.

The various relative positions of cyclone and anticyclone are practically interminable. It is only as instances of some of these that the above illustrations have been given. As a matter of fact, owing to our geographical position, the winds over the British Isles are most ordinarily governed in the main by cyclonic systems, the centres of which lie to the N.W. and N. of our coasts. From an examination of 12 years daily weather maps undertaken by the author it appears that about 63 per cent. of our daily weather maps show, over a portion at least of our islands, winds of the cyclonic type, although in 8·4 per cent. only is a barometric minimum shown actually within the limits of our coasts; and finally in 68·4 per cent. pressure is lower on our N.W. than on our S.E. coasts. These facts explain why over our district of the globe the prevailing winds are from points between S. and W., and, when we come to treat of the weather which characterises the cyclonic systems, we shall also see why our most ordinary weather is what we find it to be.

COURSES OF CYCLONIC SYSTEMS.

The question which now has to be considered is this,—what is known of the course of these disturbances whose changes of position mainly determine our changes of wind?

Course of barometric depressions.

It has long been recognised as a general rule that in our own part of the world the barometric depressions travel from the West to the East. Any long-continued series of charts giving the paths or trajectories of the barometric mimina shows this general rule to be fairly trustworthy as regards the British Isles in

The course of barometrical depressions.

particular. So much is this the case, that although, as already shown, our winds are most commonly under the influence of some cyclonic circulation, and although these systems are, in the majority of cases, moving onwards, an instance in which one of them passed from due East to due West across the Northern part of the British Isles can scarcely be found, and the cases in which they have thus crossed the South of our islands are very rare; the cases also in which they have been known to travel to N.W. or S.W., and especially the latter, are with us by no means common.

Why it cannot be exactly foretold.

The observer who is not, at any given time, possessed of information of the wind and pressure conditions at other stations than his own may often, as will presently be seen, derive from local weather and cloud observations certain useful indications of the probable course of a depression, when a depression is in his neighbourhood. But in the first place the causes which determine the course of depressions are not fully known. In the second place, so far as they are known, it is certain that the course of depressions is generally related to the distribution of pressure over a very large area; so large an area that the study of all the telegraphic reports received at the Meteorological Office does not render it possible to determine the path of the centre beforehand with much precision. The following general rules will nevertheless be found practically useful to those who can only obtain the weather maps of previous days, or even to persons who cannot obtain access to these.

Cyclones travel round anticyclones.

I. With one important class of exceptions the cyclonic systems commonly advance in such a direction as to keep the anticyclonic on the right of their course. Thus, when an anticyclone lies to the S.W. of our islands, the cyclones pass South-eastward from Scotland down the North Sea towards Denmark and Germany. When the centre of an anticyclone lies over England or the North of France the cyclones pass North-eastward well outside the Irish and Scotch coasts, then Eastward to Norway and Sweden, and afterwards South-eastward towards the South of Russia. When, again, an anticyclone lies over Denmark, Scandinavia, or the Baltic, the cyclones pass Northward over our Western coasts.

Exceptional cases.

II. The exceptional cases referred to are those in which, in our regions of the globe, a cyclone lies on the immediate South of an anticyclone. The former then remains nearly stationary for some time, or else retires in an erratic manner commonly towards South or South-east.*

Prevalent courses in summer and winter respectively.

III. The great majority of those cyclonic systems by which our winds are affected travel towards Europe from some part of the North Atlantic, and, as already remarked, their centres in most cases pass outside the confines of our shores. This is especially the case in summer, when the prevalent course of the larger systems is in the comparatively high latitudes of the Atlantic. In winter the general march of the large depressions is nearer to our islands, and it is also in this latter season that the causes which promote the development of these extra-tropical oceanic cyclones are commonly most energetic. It is thus that in winter there is produced that area of very low mean pressure which is shown in Plate I., stretching from the South of Iceland towards Nova Zembla and the North Cape. A majority of the cyclonic systems whose centres pass actually over the British Isles, are of comparatively small dimensions, and the course of the small systems is less erratic, or more regularly to the east, in winter than it is in summer.

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* See Journ. Scot. Met. Soc., xlviii., pp. 330-335.

Influenced by nature of surface of ground.

IV. It has also been observed that the cyclonic systems are to some extent affected in their course by the nature of the surface of the ground, having a tendency to skirt along a coast line or a mountain chain instead of passing inland or across the mountains. Thus they frequently skirt the North coast of Scotland or pass up the Irish or English Channels in preference to travelling directly over the more inland stations.*

Sequence discernible.

V. Finally, a sort of sequence is discernible in the cyclonic disturbances. They are rarely solitary, but usually follow one another in a kind of string or series, the behaviour of each system commonly bearing some resemblance to that of its immediate predecessor. Our most disturbed weather thus occurs in periods. These periods are, especially in winter, occasionally of some weeks duration, and while they prevail our winds back and veer with a certain amount of regularity, according as they are affected by the advancing or retiring segments of the depressions.

Secondary depressions.

VI. During the progress of a large depression our local winds and weather are not unfrequently affected by the occurrence of a phenomenon which deserves particular notice. One or more "secondary," or, as they are sometimes termed "subsidiary," depressions of small extent are developed near the exterior of the primary or larger system. These commonly deserve the name of "hemicyclones" rather than of "cyclones," for the more general barometric pressures being much lower on one side of them than on the other, their isobars, as represented on the weather map, frequently do not form closed curves; thus, while a brisk current occurs on their exterior side, or that furthest from the centre of the larger depression, on their interior side the general current of the larger system is often only checked or abated for the time instead of being reversed. These secondary disturbances hardly ever occur on the left-hand side of the trajectory of the primary system. They commonly originate a little in the rear of the latter, and occasionally continue to accompany it in this position; but more frequently they travel nearly round the whole right-hand half of the large depression, moving with greater velocity than the latter. On arriving in the front they exhibit themselves as bulges in the advancing isobars. Their further behaviour seems to be ordinarily determined by the general atmospheric conditions of the district into which they have thus penetrated. If the barometric pressures in front are generally high, and the atmosphere dry, they become "filled up" and disappear. If, on the other hand, the conditions are favourable to

Their characteristic positions.

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* Scott, "Weather Charts and Storm Warnings," p. 88

their ulterior development, they commonly advance as independent cyclonic systems. There is reason to suppose that many of the smaller depressions which travel rapidly from West to East across our area have been secondaries detached from a larger depression on the Westward of our shores. It thus commonly happens that the local Northerly current in the rear of such systems is very transitory, being speedily replaced by a portion of an extensive Southerly or South-westerly wind.

The occurrence of secondary disturbances is not unfrequently a cause of embarrassment to the observer who attempts to forecast wind and weather from local observations only. However, the weather which accompanies these phenomena has a somewhat distinct character of its own.

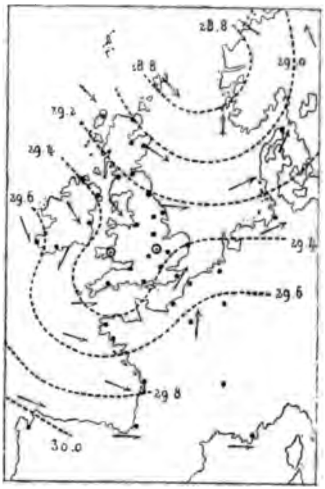

Fig.10. _ 4 Oct.1873. 8 am.

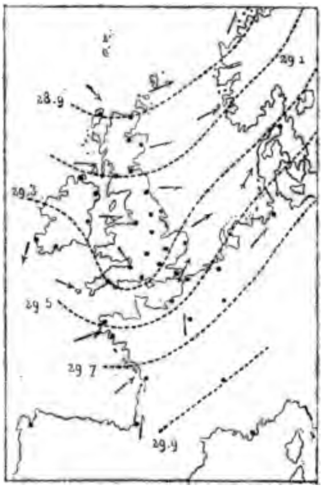

Fig.11. _ 7 Oct.1874. 8 am.

Large cyclones accompanied by secondary systems.

Figs. 10 and 11 show secondary systems in their characteristic position relative to a larger cyclonic circulation.

The anticyclones present a great contrast to the cyclones in this respect that instead of shifting their geographical position rapidly, they are exceedingly sluggish in their movements; and indeed frequently remain stationary for a very considerable period.

Anticyclones often stationary.

The remark already made (page 15) as to the inference to be drawn of the existence of vertical currents from the maintenance of the horizontal, applies with as much force to our local wind systems as it does to the general atmospheric circulation of the globe: and the observations of upper currents equally confirm these conclusions.

Inference as to vertical movement of air.

THEORY OF CYCLONIC SYSTEMS.

It is not intended in these pages to enter fully into the theory of the movements of the atmosphere. Various hypotheses have been entertained with regard to the development and motion of the cyclonic systems; but most of these may be dismissed with the remark that they neither fully accord with observation, nor are compatible with the stationary character of the anticyclones as contrasted with the progressive movements of the cyclones. This contrast, as well as most of the general rules given in the preceding pages, is intelligible on the hypothesis, which the author is disposed to favour, that an ascending current of atmosphere occurs in the cyclonic circulations, and that this ascending current originates in the simultaneous condensation of water vapour over an extensive area. It will be seen presently that the district in which the condensation is most active occupies the front of the cyclone.

Cyclone theories.

Condensation hypothesis.

A little consideration will show that over the North Temperate Zone it is on the eastern side of a cyclone that this condition will in ordinary cases occur, since it is on this side that we have Southerly winds, while these winds, in moving from warm to colder regions, experience a diminution in their capacity for holding water vapour.

Accounts for eastward motion.

A cyclone must not therefore be regarded as a revolving disk, the whole of which is propelled over the earth's surface, but rather as an eddy of spirally ascending air, which eddy is being constantly reproduced on one side of its original position. Fresh portions of the atmosphere are thus perpetually thrown into cyclonic circulation, and it is only by a metaphor that a progressive cyclone can be said to preserve its identity during its progress.

Atmosphere ascends in cyclone.

An anticyclone, on the other hand, represents the position of a downward movement of the air, which has lost the greater part of its water vapour in previous cyclonic circulations. In the district, therefore, near the central calm of an anticyclone the currents take up instead of precipitating vapour. This explains why there is no principle of progressive development in an anticyclone, and why the cyclones in their onward course are not drawn towards the centres of the anticyclones, but skirt round the

Descends in anticyclone.

extreme exterior of the latter, for it is only the exterior currents of the anticyclones which have taken up sufficient water vapour to maintain the cyclonic disturbance.

Condensation hypothesis explains exceptional case.

The same hypothesis accounts for the exceptional fact, already noticed, that in our region of the globe a cyclone on the Southern side of an anticyclone rarely moves Westwards, since in this instance the surface winds drawn into the cyclone from the anticyclone have not only been descending currents, but have also come from higher latitudes, and are therefore especially cold and dry.

Tendency to skirt coast lines.

The tendency of the cyclones to skirt coast lines, rather than to travel towards inland districts, is probably in some measure due to the fact that the vapour on which their maintenance depends is drawn principally from the seas. But a further cause lies in the comparative absence of surface friction as experienced by their winds in passing over the sea. The irregularities of a land surface break up or check the currents passing over it, and diminish the centrifugal force of the gyrating winds. A cyclone, in short, is propagated more freely over the sea than over the land.

Formation of secondary systems.

A secondary depression, according to the hypothesis of which we are speaking, has its origin in a somewhat local Nimbus, or in a local intensification of the general Nimbus, and its inflowing and ascending current is only an imperfect spiral. The relative velocity of a secondary system as compared with its primary is possibly due to the fact that in addition to its inherent tendency to self-propagation its currents are drawn from a portion of the atmosphere which is already in rapid motion.

Sequence of cyclones.

Again, the same hypothesis throws some light on the tendency which the cyclonic systems exhibit to run in a series, a fact which it is difficult to explain, if a cyclone is regarded simply as a revolving disk. When the atmosphere over an extensive district of the surface of the globe, say, over a portion of the North Atlantic to the westward of our islands, is much charged with water-vapour, the formation of a large Nimbus is sufficient to originate a cyclonic system; but a considerable portion of the atmosphere which is drawn into the circulation never reaches the front of the cyclone at all, being left behind, as the cyclone is rapidly developed over another part of the earth's surface; this part of the atmosphere, therefore, falls calm before it has parted with its aqueous vapour, and is in the condition favourable for the propagation of another system.

Other and converging lines of evidence in favour of this theory of cyclone and anticyclone may be drawn from the behaviour of these phenomena in other parts of the world, but the whole subject may be dismissed with one important observation—that neither the dampness of the atmosphere, as measured by the hygrometer, nor the amount of water collected in a rain-gauge, affords an adequate measure of the amount of cyclonic disturbance which attends a Nimbus. The former instrument tells us nothing of the humidity of the atmosphere in general, but only of the humidity of that portion which is close to the earth's surface; and the latter instru-

Cyclonic disturbance not measured by hygrometer, or by rain-gauge.

ment tells us nothing of the altitude or of the thickness of the layer of the atmosphere from which the water has been drawn. In reference, therefore, to the dynamics of the winds the information afforded by one of these instruments is too restricted, and that of the other too vague, to be of much use. It is not surprising, therefore, that some of our shallowest cyclones are accompanied by as heavy and general rain as the deeper systems, especially when it is observed that during sluggish circulations at the earth's surface rapid currents often exist in the higher cloud regions.

Rainfall in re
of cyclone.

Inclination of
axis of cyclon

An objection to the condensation theory of cyclones is occasionally drawn from the fact that *in some cases* both heavy and extensive rainfall is found to occur in the immediate rear of a centre of depression, when travelling eastwards. Recent investigations, however, render it probable that the axis of a progressive cyclone is commonly so inclined, that at the height of a few thousand feet above the earth's surface the area of least pressure lags considerably behind the area of least pressure observed at the earth's surface.* It will therefore occasionally happen that, *over* the wind which blows in the rear of a depression, currents flow *in nearly an opposite direction* to that wind. These latter currents consequently precipitate their water through the lower stratum of relatively dry air; the condensation being due to the fact that they are chilled not only by travelling from lower into higher latitudes, but by the contact of their under surface with air which is simultaneously travelling from still higher latitudes.

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* Quart. Journal, Met. Soc., xxiv., pp 437-445; xxxi., pp. 167-174; Loomis, *Contributions to Meteorology.* (American Journal of Science and Art, January 1879.) In connection with references to other publications it may be here mentioned that the text of the present work was completed in Midsummer 1879, its publication having been, from several causes, unavoidably delayed.

III.

CHARACTERISTIC TYPES OF WEATHER.

Special Relations of Weather to Cyclonic Systems.

Weather variations.

It remains to describe, from the purely observational point of view, the conditions of weather, states of cloud, &c. which commonly characterise the more important types of the atmospheric currents. The same difficulties which have beset the earlier part of this discussion continue to attend it here, and the reader must again be reminded of their nature. The weather is largely influenced by purely local conditions, and the observer in his use of the sketch about to be given, must make the necessary allowances for these local influences, very few of which can be mentioned as we proceed, and those only by way of illustration. Again, the weather which accompanies the various forms of pressure distribution is largely affected by the season of the year. This class of variations it will be important, as far as possible, to determine. Lastly, there remain a great number of modifications which may be termed accidental, or in other words, which depend on conditions either unknown, or not as yet reducible to definite law or fixed classification. More cannot be attempted here than to indicate the limits of these modifications, with the view of conveying some idea of the most distinct and prevalent weather types.

In the most general way it may be stated that foul weather characterises the cyclonic, and fair weather the anticyclonic systems; and it will at once be seen that to this statement corresponds the old but loose and vague rule that the barometer falls before rain or storm, and rises before fine or calm weather. But the weather thus belonging to cyclone and anticyclone differs considerably in the different seasons. It varies yet more, as already implied, in the case of cyclones, in the different districts of the cyclonic system, that is to say, in the relation of these districts to the path of the centre, and in their distance from the centre. The weather which characterises the several districts of the cyclonic systems will be described first, and then that which belongs to the anticyclonic.

In treating of the weather characteristic of the cyclones, the larger systems will be examined first, and secondly the smaller and subsidiary systems. The reader must conceive of these systems as portrayed upon a weather-map, and he must further imagine a line drawn through the centre as representing the path of that point. He will thus understand what is meant by the front and the rear, the right-hand and left-hand portions of the system.

Front of cyclone.

In the front of a large depression, at its extreme exterior, that is to say, considerably outside those of its isobars which form closed curves, there commonly stretches a great bank or sheet of cirro-stratus, such as we have described on p. 3. The outside edge of this bank is pretty definite, and its outline in most cases is in rough correspondence with the contour of the advancing isobars. The movement of the upper-current which carries the outlying parts of this elevated cloud-bank is often nearly tangential to the edge of the cloud-bank itself, and nearly opposite to the direction of the wind which is presently about to spring up at the earth's surface, and in nearly all cases it makes a greater angle than 90° with this wind. It is important to observe that when this movement is very rapid, the approaching depression may be expected to be "deep," and probably attended by strong winds at the earth's surface. As the sheet extends over us the upper-current backs very quickly, and continues to do so over the whole of the front half of the advancing system. As the centre advances towards us, we commonly observe composite cloud (Nimbus), the rain or snow being accompanied by the new current of air belonging to the depression. This cloud-bank extends in most instances nearly over the whole front half of the system, both on the right hand and left hand of the centre's path, but its character differs very considerably on the two sides. If the centre is passing so as to leave our station on its right, the Nimbus usually continues until the centre has almost reached its nearest point to us. Then, usually after a sudden increase of precipitation, the sky clears, the cirro-stratus terminating in an abrupt line, while the wind at the earth's surface begins to veer, slightly if we are at a great distance from the centre, and greatly if we are very near it. Up to this time the barometer will have continued to fall (except in those cases in which the whole system is becoming rapidly shallower), but the rapidity of the fall will have depended, as a moment's consideration will show, on four separate elements, the first, the rate of progress of the system; the second, the steepness of its gradients; the third, the increase or diminution taking place at the time in this steepness, in other words, on the question whether the depression is becoming "deeper" or being "filled up;" and the fourth, on the distance of our station from the centre. Pressure now begins to rise (except in those instances in which the depression is becoming rapidly deeper). The appearance of the sky in the rear of the disturbance, but still on the right side of the centre's course, is usually very unlike that in the front. Comparatively few upper-clouds are observed, and the movement of these is commonly noticed to be nearly the same with that of the current on the earth's surface. In lieu of cirro-stratus we see fleecy cumulus. Shower-clouds are also common over this district. These latter, in summer, especially in our more inland regions, often take the form of local thunderstorms. In winter, passing squalls of rain, snow, and hail are common. Those on our western coasts are often attended by lightning. It should be remarked that these showers in the rear of a depression are far more extensive and persistent on exposed coasts and in hilly districts than in inland and more level countries. The atmosphere in this part of the disturbance is in most cases

Approach of centre.

Right-hand half.

Showers in rear.

clearer or more devoid of haze than in the front, and temperature is also commonly lower; but marked exceptions occur to both these rules. A rapid and excessive decrease of temperature is not uncommon when the wind has begun to veer, particularly near the centre of the cyclonic circulation.

Left-hand half.

Let the reader now turn his attention to the other side of the centre's path, and let him suppose the barometric minimum in its onward progress to leave his station on the left of its course. Here the Nimbus extends over us, the wind after springing up commences to back, and continues to do so throughout the passage of the disturbance. On this side we very rarely experience the abrupt change from a rainy to a clear sky which is so usual on the right-hand side. As the centre passes, the higher cloud forms gradually degenerate into banks of dreary stratus, often attended with an increase rather than any diminution of haze. As the rear of the system approaches us on this side the bolder forms of cumulus are rarely seen, and in place of the shower-clouds we commonly notice gloomy-looking banks of condensed vapour in the middle and lower levels of the atmosphere, while cirrus has usually almost or altogether disappeared.

Passage of centre.

Aspect of sky in centre of depression.

In the actual centre of a large depression the sky is often comparatively clear. Shower-clouds are frequently visible, but these have usually here a thin soft and disintegrated aspect, while cumulus tends to spread itself into stratus, and cirrus lies in broken, though watery-looking, patches.

Aspect of sky in secondary systems.

The above description refers to the larger and more important depressions; it cannot be applied without considerable modification to the smaller or more local systems. These latter are commonly characterised by a more unbroken cloud-bank, gloomy skies (often with rain or snow) prevailing over the central calm and even to some extent over the extreme rear of the system. The secondaries are especially marked in most cases by very copious precipitation over the district which they traverse, the rainfall being usually greatly in excess of that which occurs over the rest of the primary disturbance. In summer, local depressions, especially if they are secondaries taking a northward direction, are usually associated with heavy thunderstorms. In the front of these last-mentioned systems the cirro-stratus is commonly accompanied, and sometimes almost replaced, by the turreted stratus described on p. 4. The occurrence therefore of this form of cloud moving from some southerly point over easterly or northerly surface-winds, is a valuable indication of approaching thunder-showers.

SPECIAL RELATIONS OF WEATHER TO ANTICYCLONIC SYSTEMS.

As has already been stated, the weather which characterises our anticyclones is in marked contrast to that which belongs to the cyclones. It is, however, subject to far greater modification in relation to the seasons of the year. In summer, and especially in our hotter summers, brilliant weather usually accompanies the anticyclonic circulations, the dry atmosphere permitting the sun's rays to exercise their full heating power on the stratum of air near the earth's surface. In the central districts particularly the sky is often nearly or totally devoid of cloud; at other times light fleecy cirrus, whose motion is extremely slow, is the principal cloud visible. Near the exterior of the system, and especially on its eastern and south-eastern sides, stratus and fine-weather cumulus, often accompanied by much haze, are the prevailing cloud forms. At the extreme western and northern borders cirro-cumulus and cirrus are very common, beneath which there is fog occasionally at the sea-coast, but rarely at the inland stations. Near the south-western limit of a large and well-formed summer anticyclone remarkably brilliant and cloudless weather often prevails.

Summer anti-cyclones.

In winter the aspect of the sky in these systems is commonly very different from that just described. Dry weather stratus, such as it has been described on p. 4, is now the most common form of cloud, occasionally covering nearly the whole of the anticyclonic system with an unbroken canopy, the perpendicular thickness of which is very small, though its extent is so immense. Above this, in the higher regions of the atmosphere, there is in such instances a remarkable absence of cloud; while beneath it dense ground fogs very commonly prevail at the inland stations. In some cases, however, the sky is almost devoid of cloud, or the ground fog only prevails. In these latter instances the temperature of the air is very low, whereas in the clouded anticyclone we usually experience only a moderately low temperature, the cloud-layer checking the radiation. Near the exterior of the system the atmospheric currents usually break up, to a great extent, the canopy of cloud and land fog. On the eastern and south-eastern limits of the system the appearance of the clouds is often very similar to that which prevails in the same district of an anticyclone in the summer, but banks of the dry stratus are even here more common than true cumulus. It is most usually in this district that the temperature is the lowest in our islands, a fact that is due rather to our geographical position than to any other cause. Occasionally, however, we experience, as in summer, an exceedingly clear sky on the south-western side of a large anticyclone, which in winter is accompanied by intense frost. It may be said generally that the occurrence in any marked degree of the form of cloud which has been distinguished as "dry-weather stratus" is commonly an indication of an anticyclonic movement of the air, and a thoroughly well-trained cloud-observer can, in many instances, tell by a glance at the sky whether the wind at his station is anticyclonic or cyclonic in character.

Winter anti-cyclones.

The anticyclones, especially if well developed, are often, as already stated, nearly stationary for a considerable period. They finally in a majority of cases break down or retire under the influence of large depressions, which approach our western or northern shores from

Termination of anticyclone, difficult to foresee.

the Atlantic. It is extremely difficult from observations made at a single station to foretell with anything like certainty the ultimate fate of a nearly stationary anticyclone, especially if the atmosphere be not only clouded, but foggy. The observer who watches narrowly the movements of the barometer, together with the slightest indications of a rising breeze, may hazard a probable conjecture on this subject. The stability, however, of these systems is itself an assistance to him in making his usual forecasts, since, by depending on this alone, he can mostly predict, for some little time in advance, that there will be no very important change.

SPECIMENS OF FORECASTS.

In conclusion a few examples may be given of the sort of forecasts which an observer can make even without the aid of the weather-maps. The reader must not treat these examples as special types for which he is to be on the look-out, or in which, when they occur, the forecasts given are to be employed in a mechanical manner. As has been already implied, the various weather conditions are practically innumerable, and consequently, if an attempt were made to frame rules of prognosis, based on a rigid ideal division of those conditions, such rules would prove worse than useless. The following *specimens* are records of actual conditions, taken nearly at hap-hazard from a weather diary as illustrating the principles already laid down. These principles the observer, combining his instrumental and non-instrumental observations, should every day employ for himself.

1. Winter: In the rear, right-hand side, of a depression travelling to east or north-east. Barometer moderately low, rising rapidly; brisk or moderate N.W. wind; clear sky between passing showers; very transparent atmosphere; no tendency to the formation of banks of stratus; little or no cirrus.

As depressions commonly follow each other in a series, and as the direction taken by the last, as well as the absence of the more anticyclonic cloud forms, indicates the absence of any distinct anticlyclone in the west, *we expect the N.W. current shortly to fall calm, and to be followed by a fresh bank of cirro-stratus, decline of pressure, southerly wind, and rain.*

2. Winter: After a day or two of chilly W. and N.W. winds, depression in the north-east taking a south-easterly course. Wind W. or W.S.W., brisk or moderate; atmosphere mild; barometer about the mean or below it, falling rapidly; cloudy, with flying scud, rough-looking composite cloud-bank, or dense cirro-stratus.

The rapid decrease of pressure in conjunction with the aspect of the sky and with the previous weather makes it probable that the right-hand segment of a cyclonic circulation travelling south-eastwards is about to pass over the station; *N.W. to N., or even N.N.E., gale is therefore to be apprehended, with a great fall of temperature, and brisk recovery of pressure.*

3. Summer: After moderately dry weather with westerly winds and barometer about or rather above the mean (northern limit of anticyclone). Barometer about the mean and steady, or falling but little; wind S.W. or W.S.W., moderate or light; overcast with much low cloud. Temperature about or a little above the mean for the season.

The extreme right-hand portion of a depression taking a north-eastward direction is probably passing over the station; *no rain, or but slight drizzling* *showers may be expected; the wind will most probably veer a little shortly, with a clearer sky.*

4. Winter: Extreme rear, right hand, of a large depression going E. or N.E. Calm, clear, and cold; N.W. wind having died down, and cumuli and shower-clouds disappeared quickly; sheet of cirro-stratus on south horizon, edge travelling from W. or S.W.; barometer below mean, rising, but rise checked somewhat.

If the new cirrus bank had appeared further in the west, and its edge had moved from a more northerly point, the fresh depression which is probably approaching might have been expected to follow nearly in the wake of the previous system. As it is, however, there is risk of its centre passing on the south side of the observer, causing *a temporary easterly wind, perhaps gale on exposed coasts, with overcast skies, and probably some sleet or snow.*

5. Winter: After light winds and dull weather; barometer much above mean; totally overcast with low tranquil stratus, and nearly calm.

As this is probably the central portion of an anticyclone, *no immediate change can be anticipated.*

6. Summer: Barometer near its mean level, falling somewhat; E. or N. breeze; turreted stratus above (such as is described on p. 4), with some cirrus, travelling rather briskly from a southerly point.

A shallow depression is probably about to pass northward over the station; *thunder and rain may be anticipated, followed by a light wind from some westerly point.*

7. Summer: After westerly winds, with temperature and pressure near the mean. Decided rise of barometer, and very high temperature; extremely clear and brilliant sky, with very few and those only very low soft clouds. Very light W. or N.W. breeze.

The central part of an anticyclone, moving slowly north-eastwards, is likely to pass over the station. *A further increase of temperature may be expected, followed probably by bright and hot easterly winds.*

8. Winter: Extreme rear of depression moving to S.E. Steady rise of barometer; wind veering from N.W. towards N.N.E.; hazy, with some dry-looking broken stratus, and no cirrus.

An anticyclonic system may be surmised to exist over the W. or N.W. *Fine and cold, though cloudy weather, may therefore be expected, with light winds.*

9. Winter: After a period of disturbed weather, with cyclonic disturbances going eastwards. Barometer about or rather above the mean, scarcely falling; continuous calm for some hours with persistent and rather heavy rain.

The observer seems to be near the centre of a very shallow depression, whose course is not distinctly towards E. or N.E. There is, therefore, a probability that anticyclonic currents are forming in the north. *Much drier weather with a high barometer may consequently be with some probability anticipated.*

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Plate I.

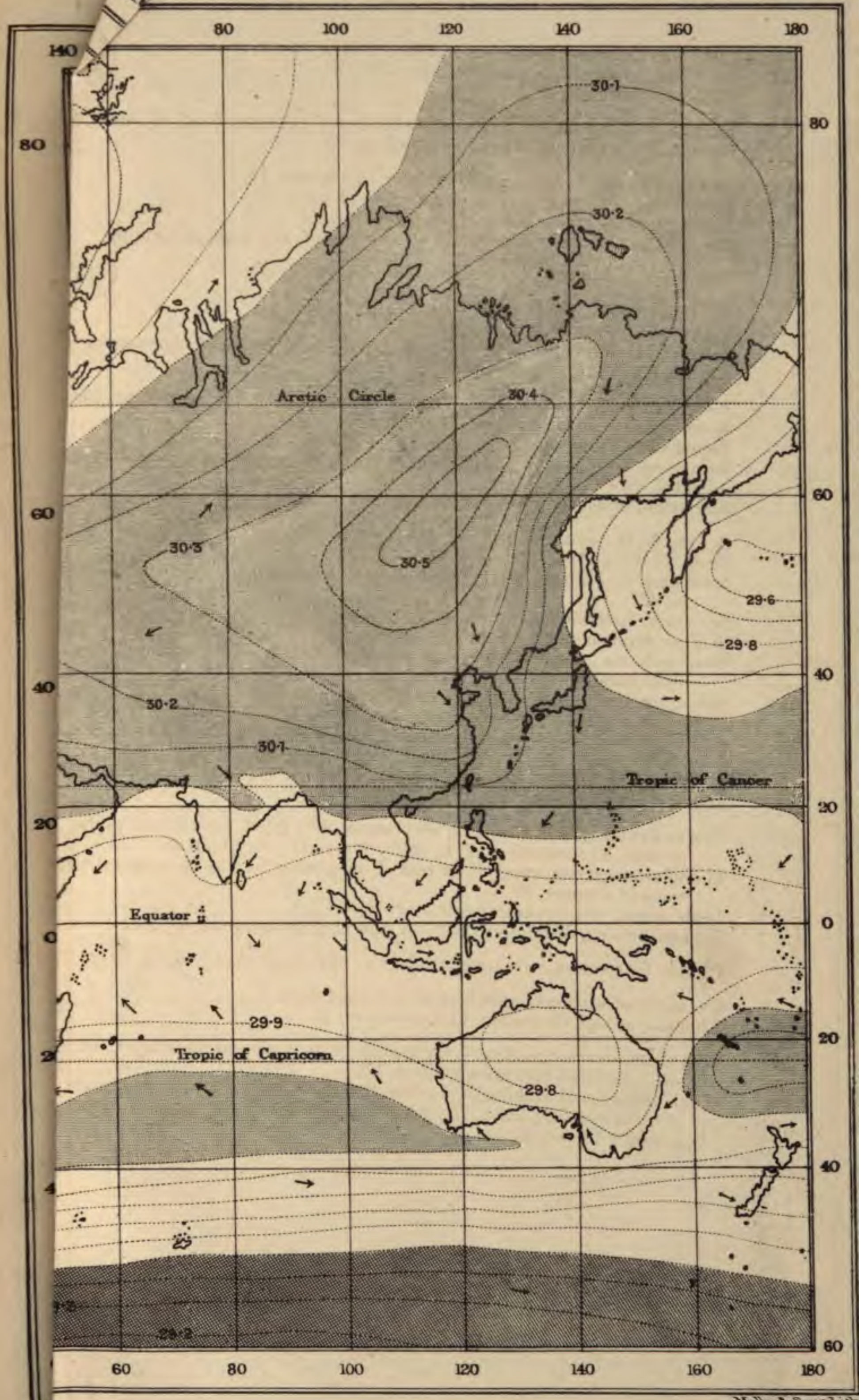

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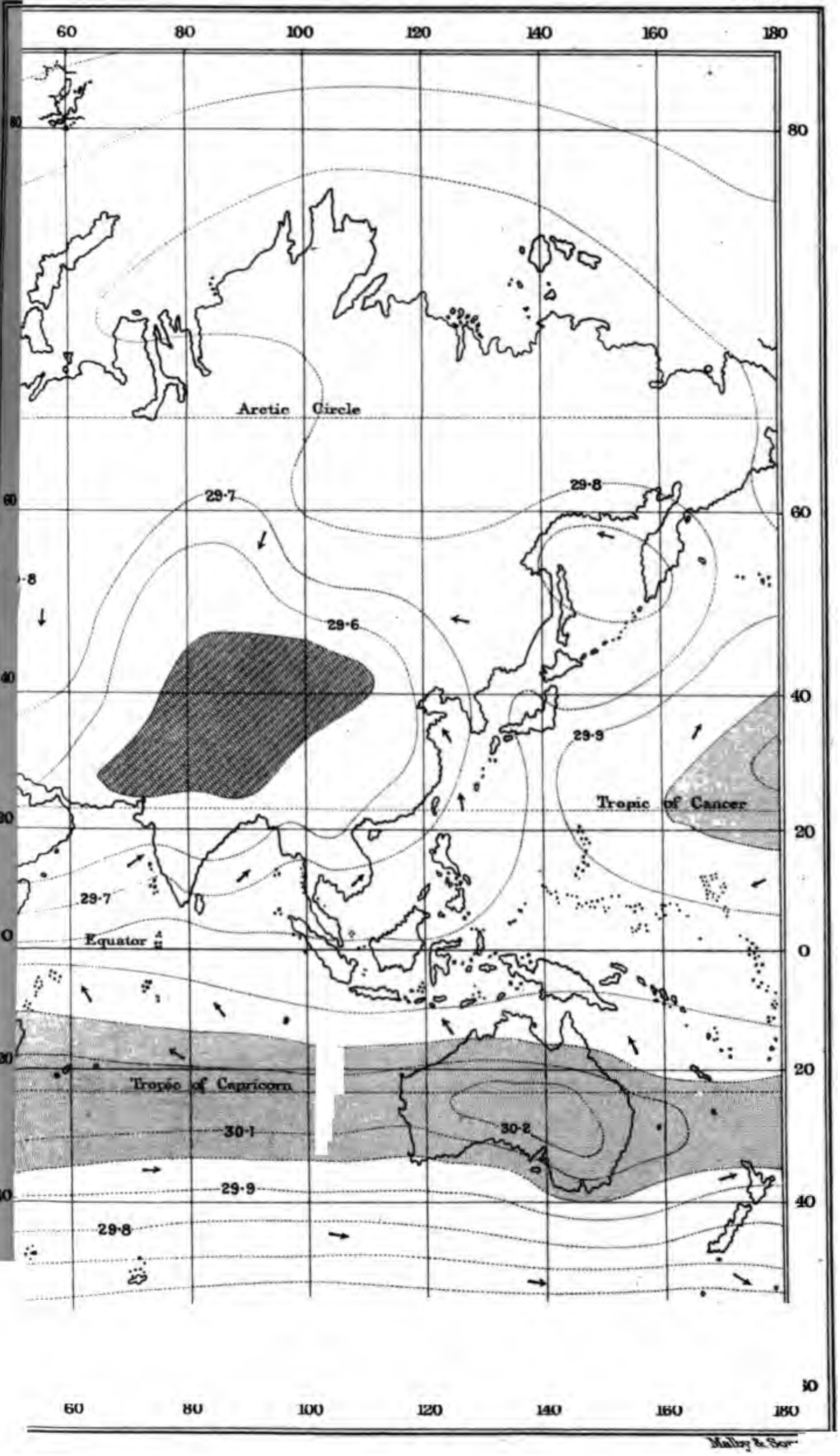
Plate II.



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